Armed Forces College of Medicine

AFCM

Bone 2

(Bone matrix and Types of bone)

Prof. Dr. Mona Raafat

Histology Department

INTENDED LEARNING OBJECTIVES (ILO)

By the end of this lecture the student will be able to:

1. **Describe** the microscopic structure of bone matrix and types of ossification
2. **Compare** between mature and immature bone
3. **Describe** the microscopic structure, functions and sites of the compact bone and cancellous bone.
4. **Discuss** the different ways of bone growth in length and width
5. **Interpret** the defective microscopic bone structure in various diseases

Key Points

- Microscopic structure of bone matrix.
- Microscopic structure of periosteum & endosteum.
- Differentiate between immature & mature bone.
- Histological structure of compact & cancellous bone.
- Differentiate between intramembranous & intracartilaginous ossification.
- Bone growth, remodeling & medical application.

Bone Intercellular Substance (Matrix)

- 25% water

- 75% hard substances:
  1. Organic components 35 % (osteoid tissue)
  2. Inorganic components 65 %

Hard substances

Organic (35% dry wt)

1- Type I collagen fibers (90 %) → acidophilic

2- Macromolecules as:

- **Proteoglycans core protein** with covalently attached side chains of glycosaminoglycan **(hyaluronan, chondroitin sulfate and keratan sulfate)**

- **Adhesive Glycoproteins (Osteonectin)**

-Vit K dependent (Osteocalcin)

Inorganic (65% dry wt)

Calcium & phosphate

In the form of Calcium hydroxy apatite crystals

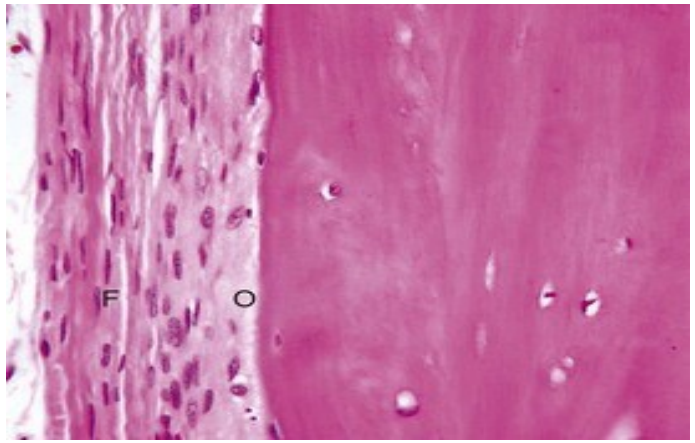
(Na, K, Mg, HCO_3 in small amount)

- The matrix is deposited in the form of bone lamellae (calcified osteoid tissue).
- It is acidophilic with many lacunae inside which the osteocytes present in between these lamellae and their processes inside canaliculi.
- It is vascular.

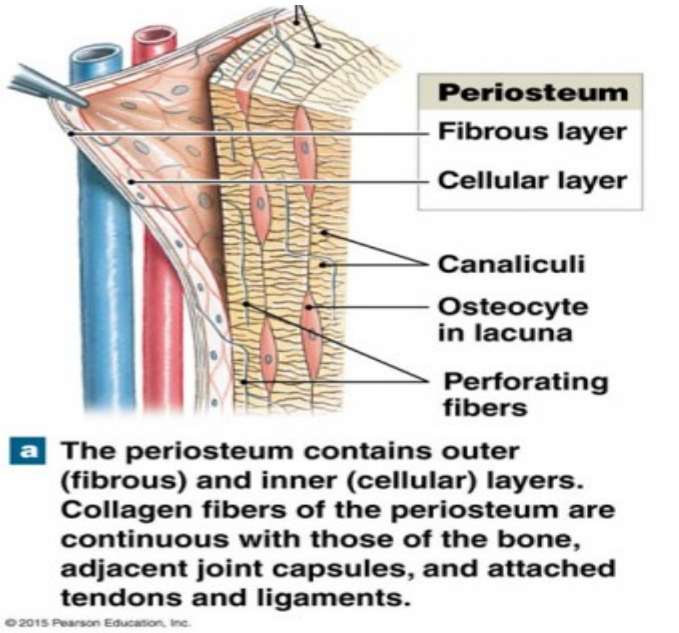
Give reason or Explain:

Bone is deformed in patients suffering from scurvy "vitamin C deficiency"

- Due to defective formation of collagen as collagen I is the main constituent (90%) of bone matrix



https://veteriankey.com/wp-content/uploads/2016/09/B9780323075336000164_f016-016-9780323075336.jpg



http://clickmypicture.com/wp-content/uploads/2019/04/periosteum-the-periosteum-and-endosteum-anatomy-physiology-anatomy-templates-728x570.png

Periosteum

Outer fibrous layer

Inner osteogenic (cellular) layer

Dense irregular C.T.

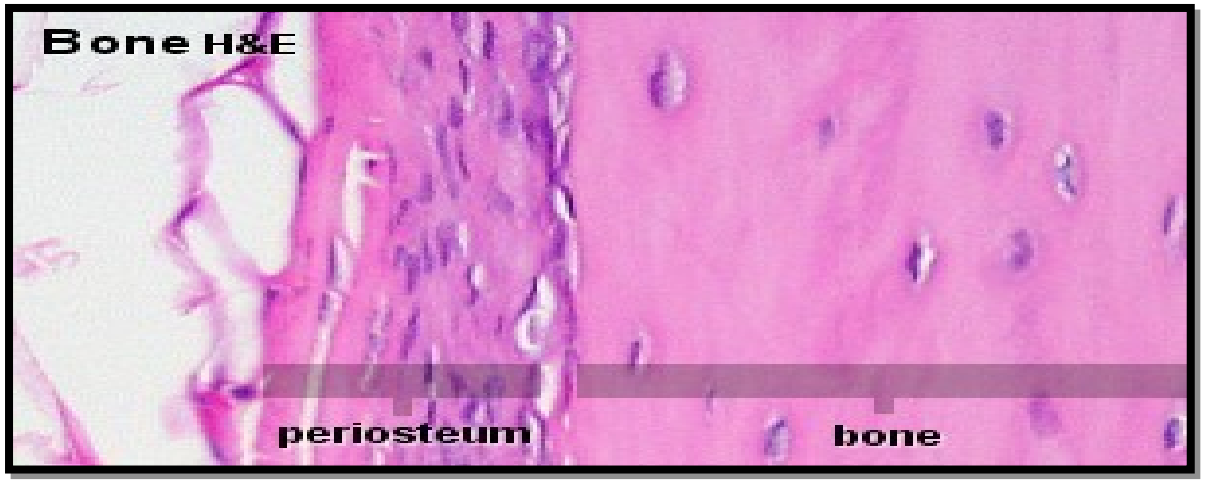
Collagen I
Fibroblasts
Fibrocytes &
blood vessels

Loose C.T.

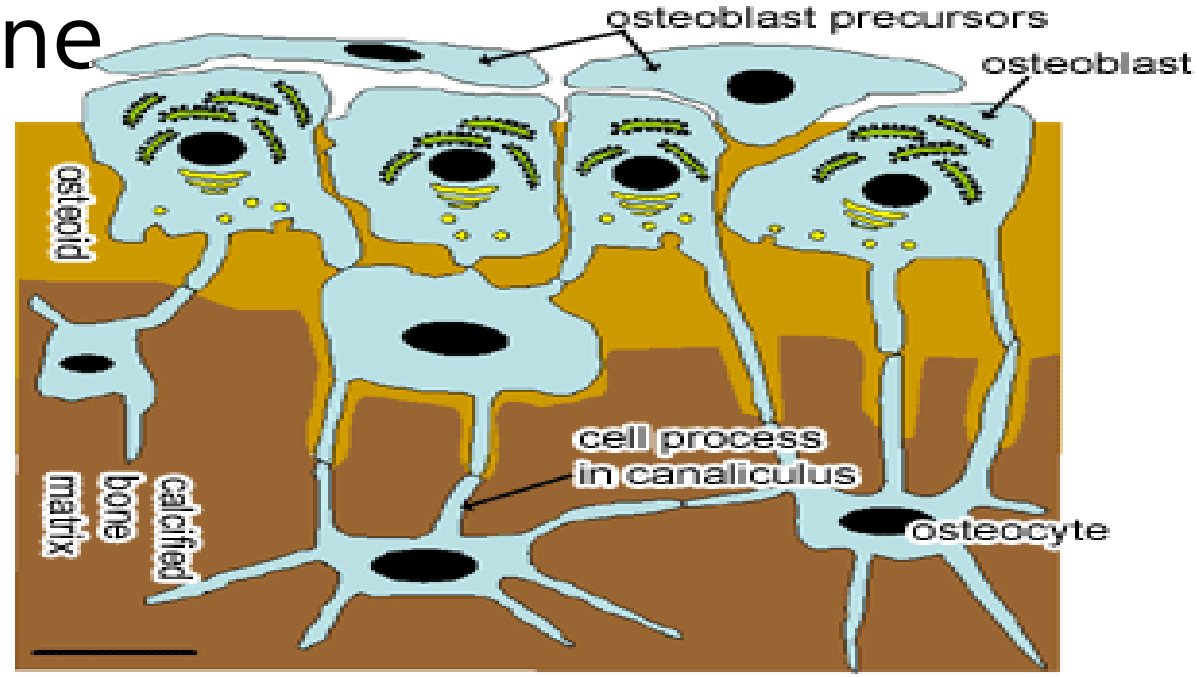
Blood vessels
Osteogenic cells
Osteoblasts

Function of the Periosteum:

1. Nutrition of bone.
2. Attachment of muscles & tendons
3. Appositional growth of bone
4. Repair of bone fractures



http://www.lab.anhb.uwa.edu.au/mb140/CorePages/Bone/images/pos20he.jpg



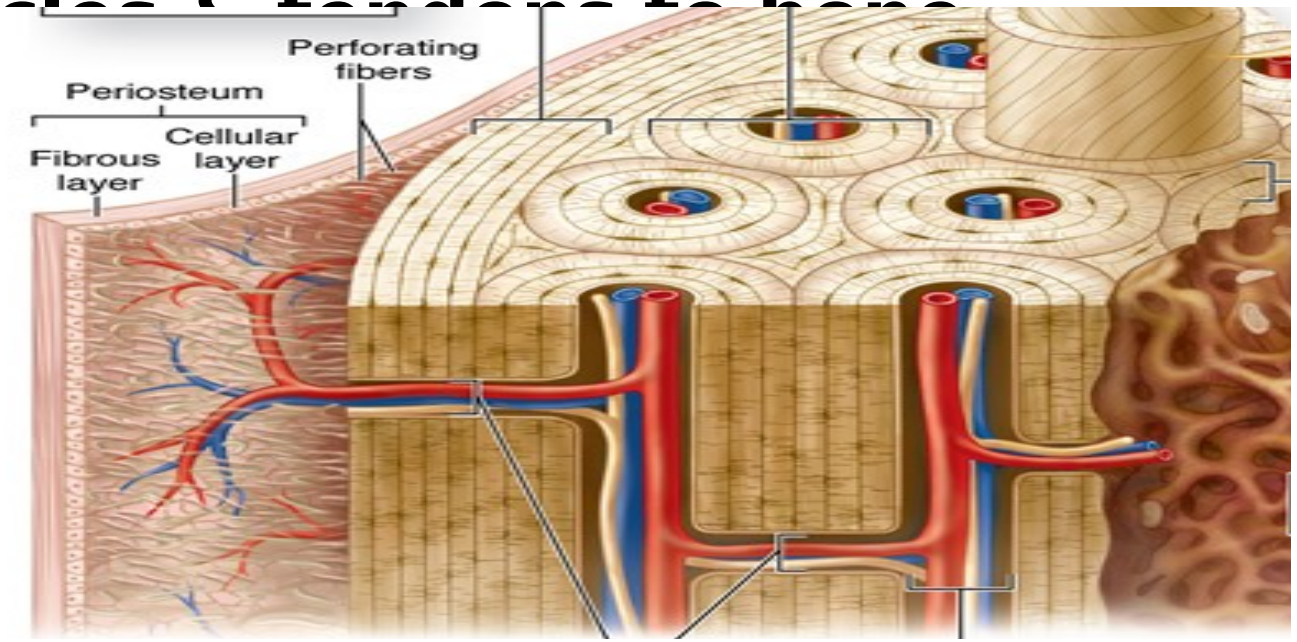
http://tse4.mm.bing.net/th?id=OIP.lHEJ8fBGXOVcv1SrPgPrXAHaGa

The perforating fibers of Sharpey's:

- Are periosteal **calcified collagen fibers** anchoring and fix the periosteum to bone matrix.

- They extend from periosteum → penetrating bone thickness.

- They fix mu[illegible]



http://histonano.com/books/Junqueira's%20Basic%20Histology%20PDF%20WHOLE%20BOOK/New%20folder%208/loadBinary_009.gif

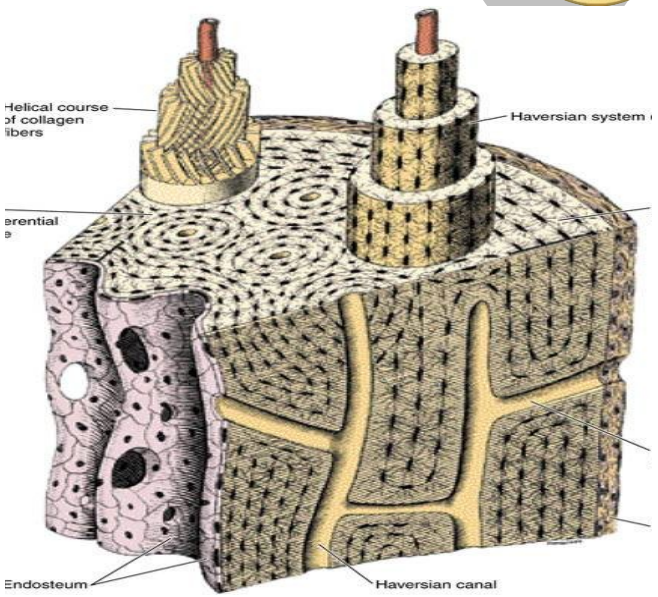
Endosteum

-Is **thinner** than periosteum & covering all **internal** cavities of bone

-Line the bone surfaces and cover trabeculae of internal cavities of bone.

Small amount of vascular C.T.

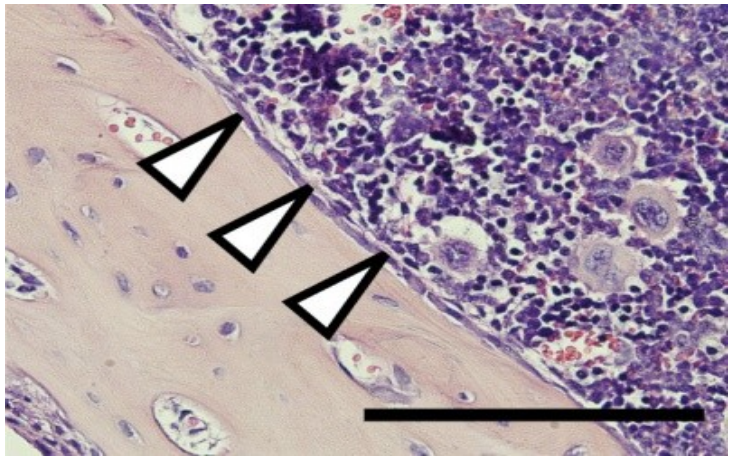
osteogenic cells, osteoblasts & **osteoclasts**



http://intranet.tdmu.edu.ua/

Function of the Endosteum:

1. Nutrition of bone.
2. Appositional growth of bone.
3. Repair of bone fractures & remodeling.

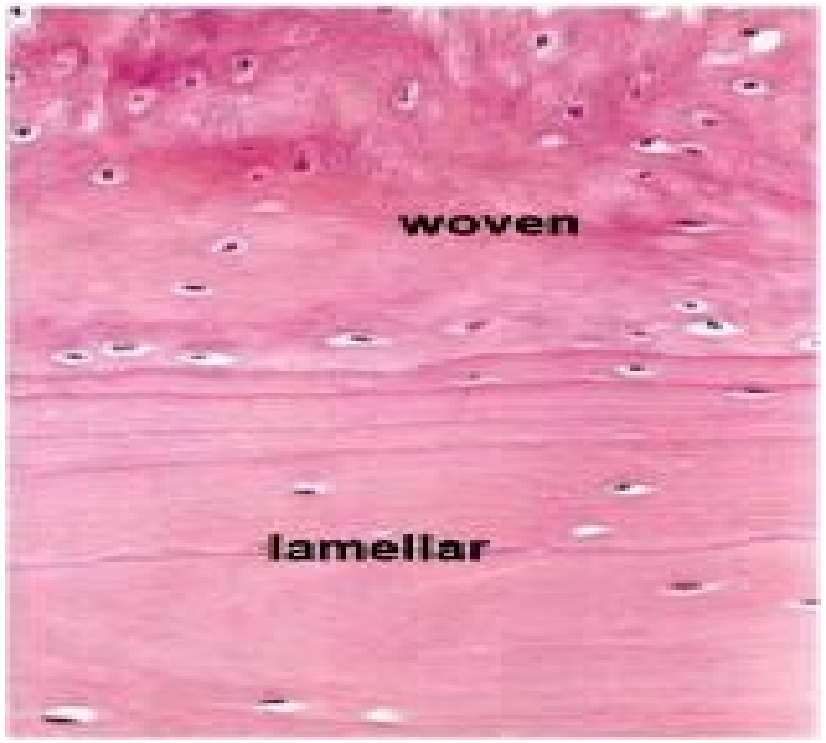


http://tse4.mm.bing.net/th?id=OIP.Lazgw8hedoHVFgrdMECcEAHaFj

Types of Bone

1- According to maturity

1. **Immature bone (primary or non lamellar or woven bone)**
2. **Mature bone (secondary or lamellar bone)**



https://1.bp.blogspot.com/-iODyUpcVFCQ/WMTRXgJ80vI/AAAAAAAAAOw/Oamm5UT0v9IK2qb8TF_gDyipBdMiwYungCK4B/s400/27566566_m.jpg

Woven/Immature/Non-Lamellar Bone

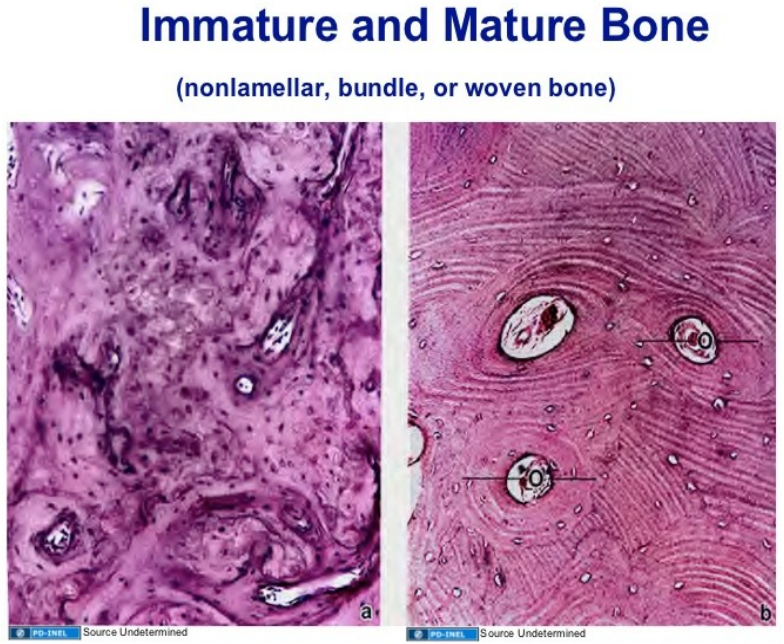
- It is the **first bone to appear** (in fetal development and bone fracture repair).
- It is **temporary tissue** which is soon replaced by mature lamellar bone.

It is characterized by:

- **Higher contents** of water, cells and organic amorphous component
- **Decreased mineral** content.
- **Bundles of collagenous fibers** run in different directions.
- Woven bone **is flexible** , **easily deformed and weaker** than mature bone.

In adults it is seen in:

- Tooth sockets
- Near suture lines in the skull
- Insertion sites of tendons
- Areas of bone repair



https://image.slidesharecdn.com/101308-histo-bonegrowthho-111024180049-phpapp02/95/101308-histology-bone-formation-and-remodeling-27-728.jpg?cb=1319719485

Lecture Quiz

-The outer covering of bone is called:

a. Perimysium
b. Periosteum
c. Perichondrium
d. Endosteum

Lecture Quiz

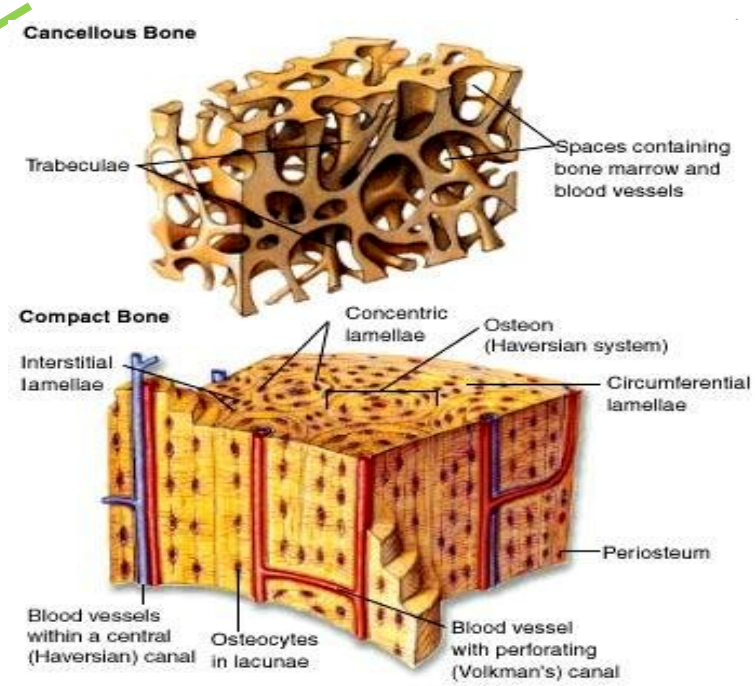
-The following are characteristics of immature bone EXCEPT:

A. Large number of osteocytes
B. Low mineral contents
C. Minute contents of proteoglycans
D. Irregular arrangement of collagen fibers

Types of Bone

2- According to the arrangement and regularity of bone lamellae, bone can be classified into:

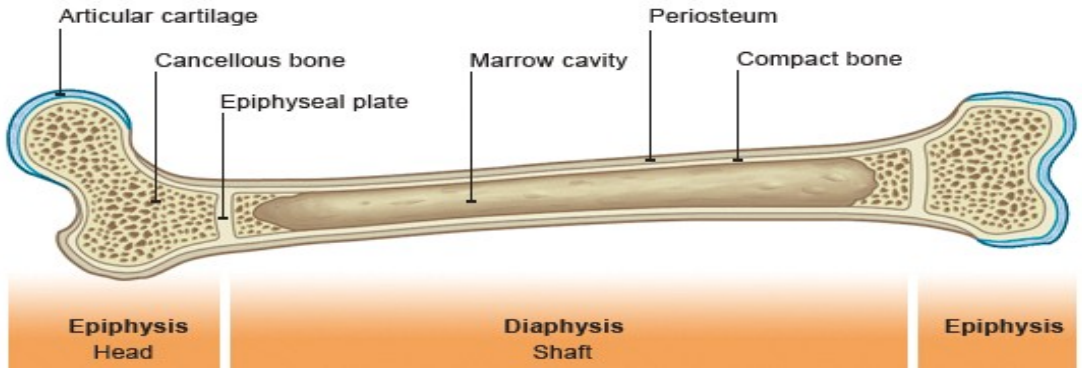
Compact bone (Cortical)



Cancellous (Spongy bone) (Trabecular)

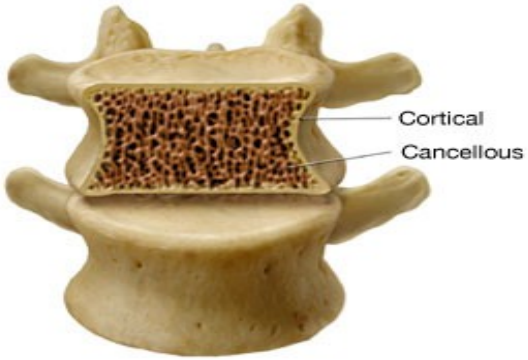
https://www.picturesso.com/thumbs/MuWGzHd7fME3KsZyleI7DGJ_YjXD0l3mrYNQb9nneMfYt6hq6cX8khNRXyeEmRyAWsA06uZ6LjdtRIiQ4ghu7g.jpg

1. **Compact (ivory or regular)**
   a. **Shafts** of long bones (diaphysis).
   b. **Outer and inner tables** of flat bone.
   c. **Outer covering** of small or irregular bones.

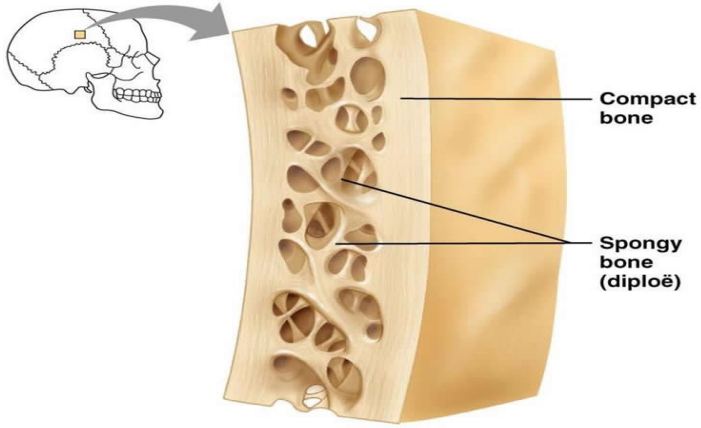


https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQE27uq88I-PEitvBMlJrOsO8RYAC_GTMqaZopBSnRkJTotxXL1

2. **Spongy (cancellous or irregular)**
   a. **Epiphysis** of long bones.
   b. **Body** of vertebrae.
   c. **Middle diploe** of flat bone
   d. **Shaft** of the ribs.



https://www.google.com.eg/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiE9aCGkJHiAhUux4UKHQsTDm8QjRx6BAgBEAU&url=https%3A%2F%2Fslideplayer.com%2Fslide%2F5892054%2F&psig=AOvVaw0NkDG7eILwM0nTbzCTmKla&ust=1557583287040315



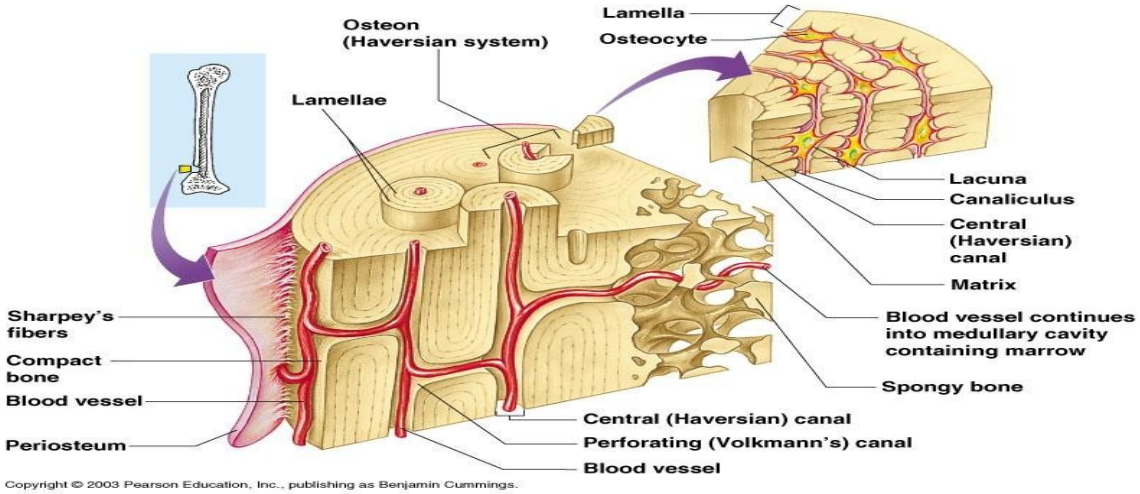
https://s3.amazonaws.com/classconnection/902/flashcards/4937902/jpg/flat_bone_anatomy_-1530FA7E2346E03FA99-thumb400.jpg

1- Compact Bone

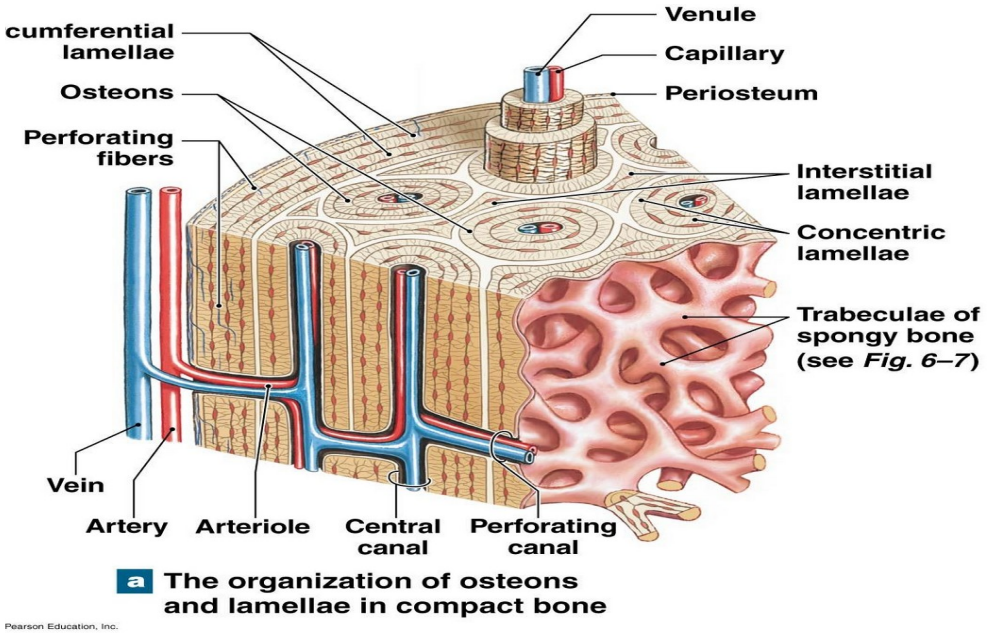
It is a solid ivory type of bone formed of regularly arranged lamellae.

Taking a section in the shaft of a long bone, 3 zones are recognized:

Outer, Intermediate & Inner zone



https://1.bp.blogspot.com/-jHj8ZePs65g/W0B787Nmt3I/AAAAAAAAAJY/vqHE0hp38bYZqKxJlKRNxV-9lVJz5xgLACEwYBhgL/s1600/bone%2B2.jpg



https://i.pinimg.com/originals/26/d5/67/26d567eff5c9e6d3d83ed07f93500508.jpg

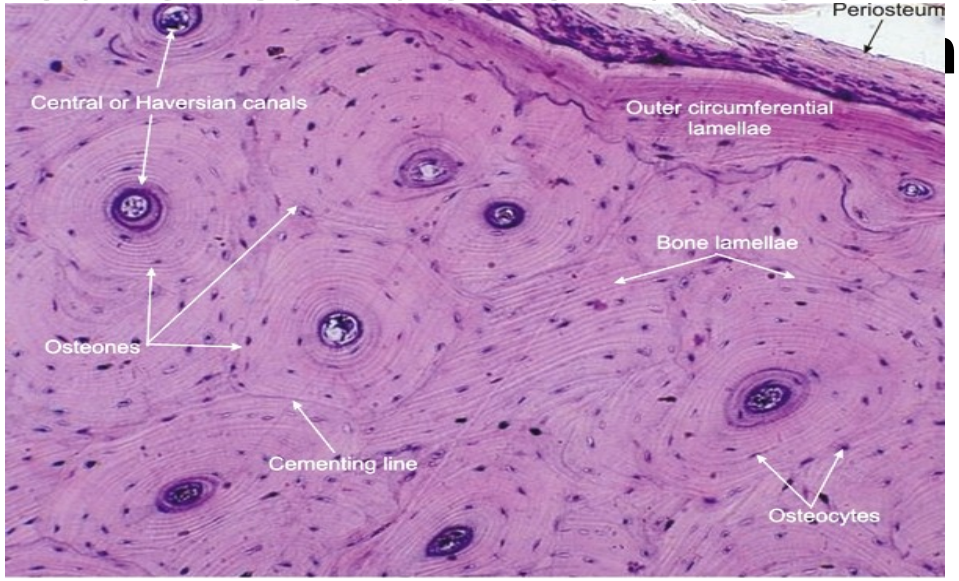
A) Outer zone:

Periosteum

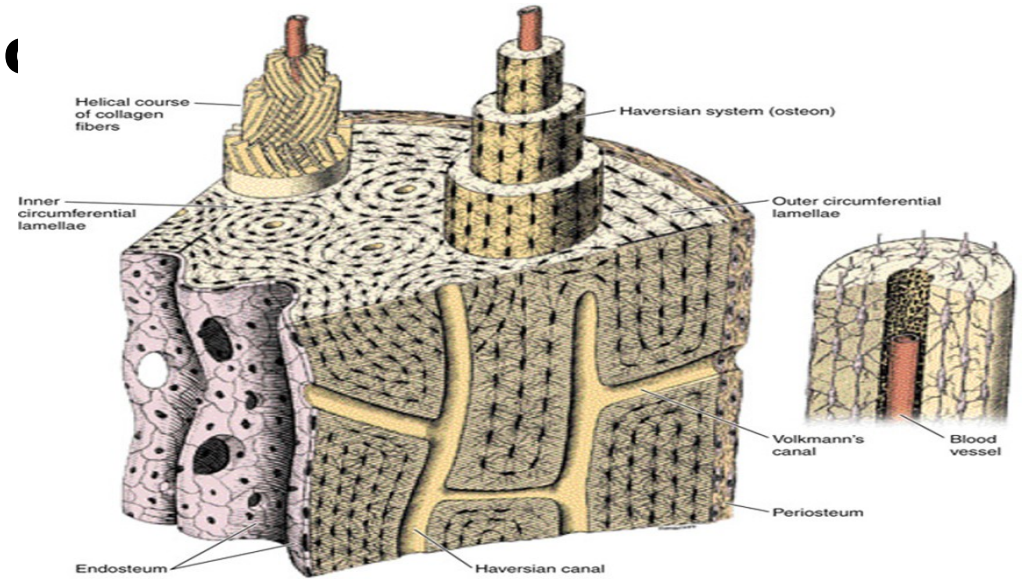
- **Outer surface is covered by a periosteum formed of 2 layers.**

Outer circumferential lamellae

- **Calcified bone lamellae regularly arranged parallel to the outer surface of bone.**
- **…side la…**



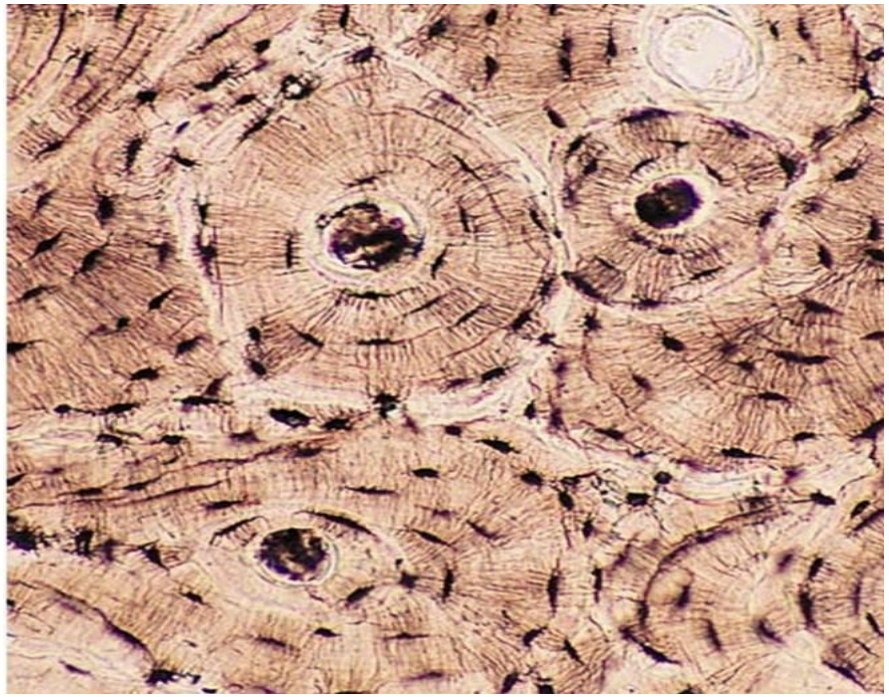
http://tse2.mm.bing.net/th?id=OIP.M_lw0QRpczqpn6K9gh9twAHaFl&w=230&h=170&rs=1&pcl=dddddd&o=5&pid=1.1



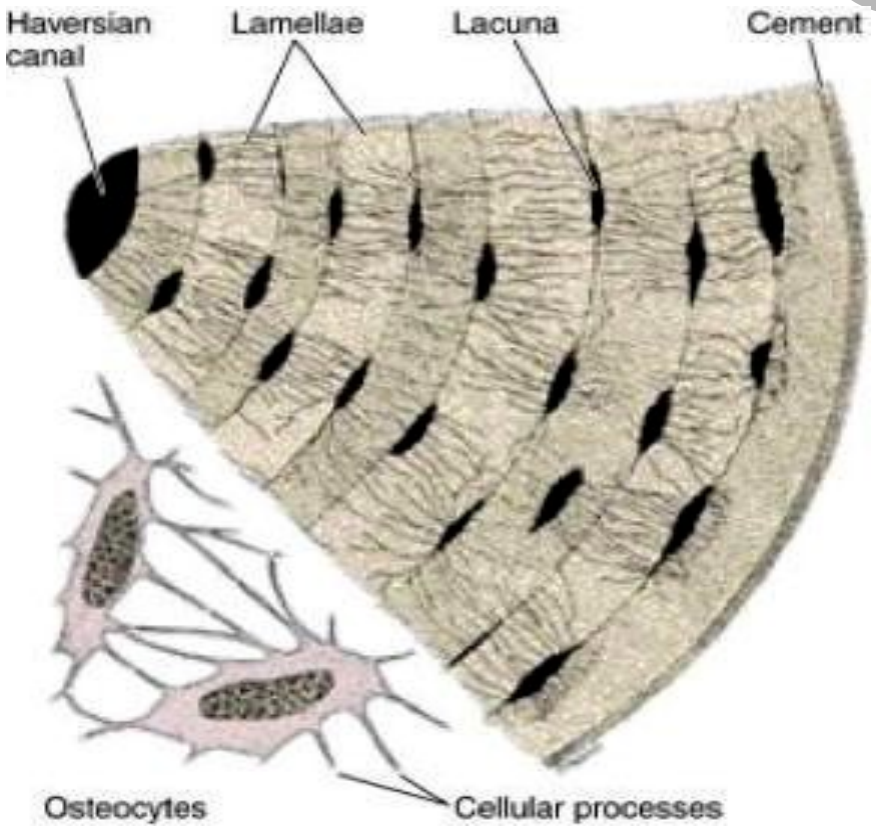
https://www.researchgate.net/profile/PJ_French/publication/224629852/figure/fig1/AS:669979737325603@1536747025808/Bone-matrix-structure-from-1_Q320.jpg

B) Intermediate Zone

1- Haversian system (osteon)
2- Interstitial lamellae



https://s2.thingpic.com/images/oL/ReKqQ2gTKmggUxZoCZ97j3Wv.jpeg



https://i.pinimg.com/originals/64/da/37/64da37873b14c713cac38fbb07f90f4d.jpg

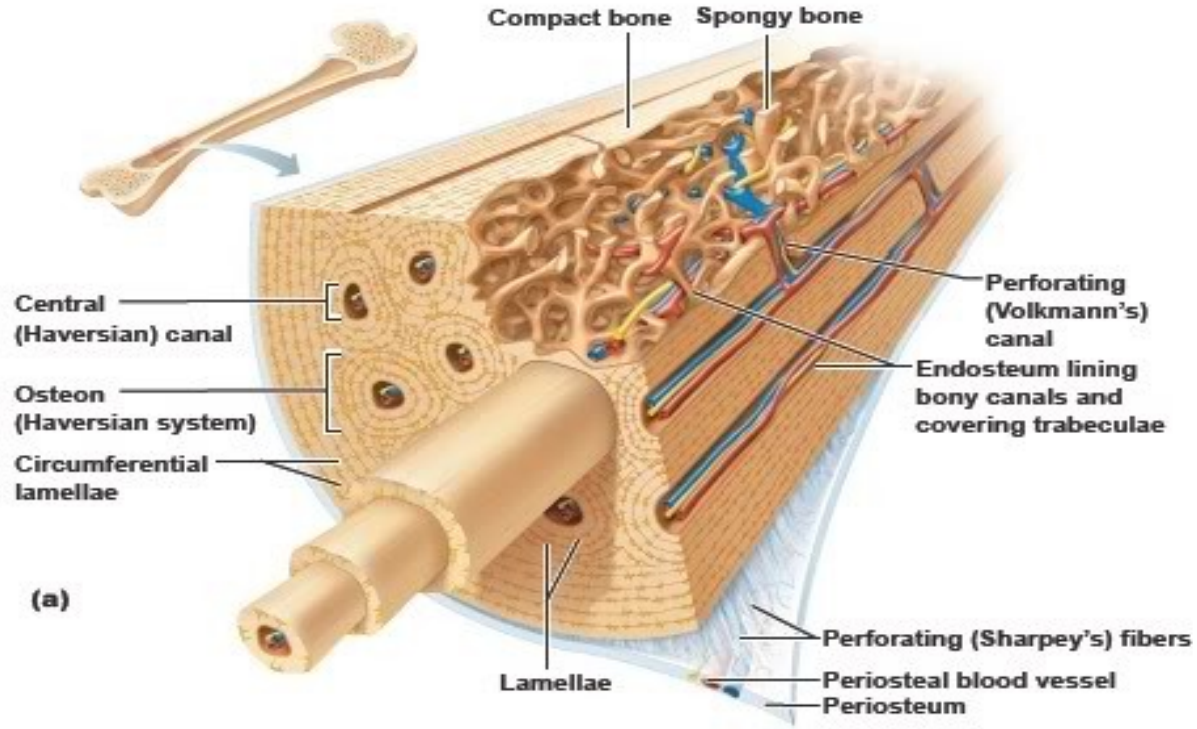
- **Each osteon is surrounded by cement line.**

1- Haversian system (osteon)

It is the structural unit of compact bone
It is formed of :
Haversian canals - bone lamellae - bo

- **Haversian system is composed of cylinders of concentric types of bone lamellae (5-20).**
- **Extend through the long axis of bone.**
- **Osteocytes inside their lacunae are present i lamellae surroundi al (Haversia**

https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcSPiV29op31HPEQV8ZprkfJhlNuwHCj00xmSdPf27RmrRGibvfY

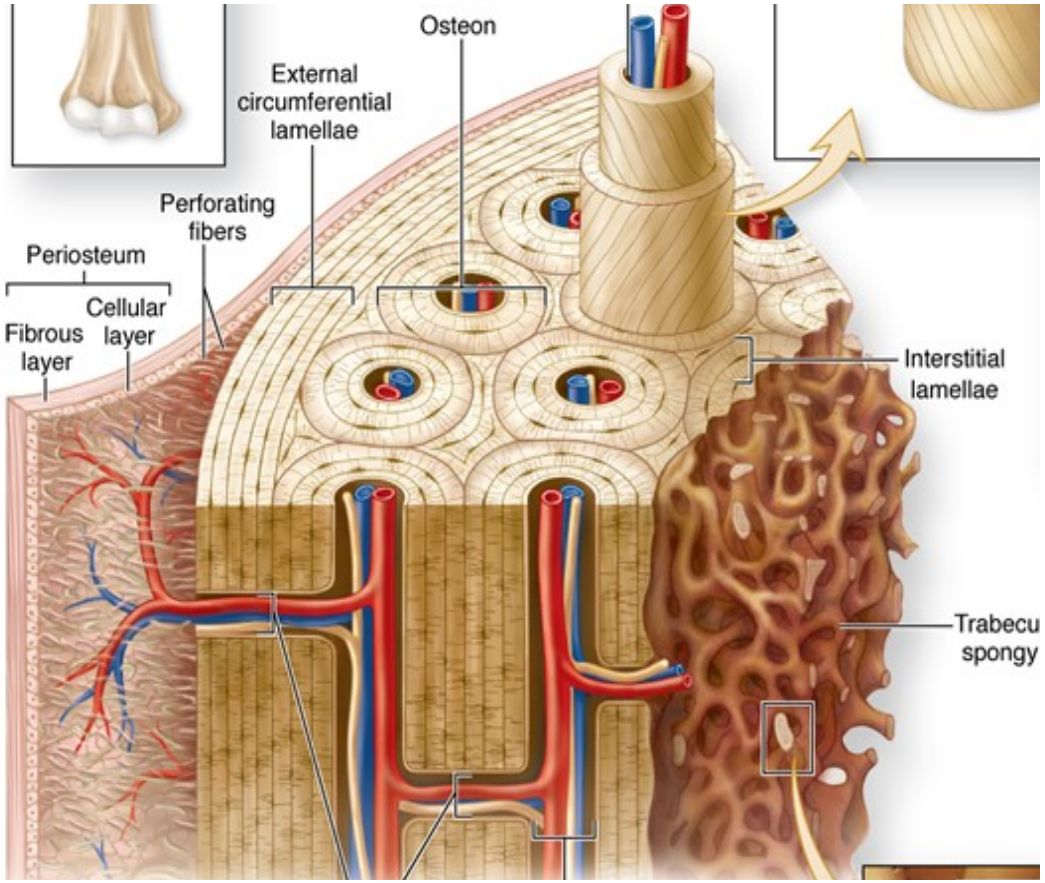


https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcSBLF35Nn9RGE4pyUZtWlAw1jqmQwl4jqFe1A-7OQc1C9myrKH_

- **Haversian canals are interconnected by transverse or oblique canals called "Volkmann's canals".**

- **Volkmann's canals act as connecting channels between blood vessels in the canals and those of the periosteum and endosteum.**

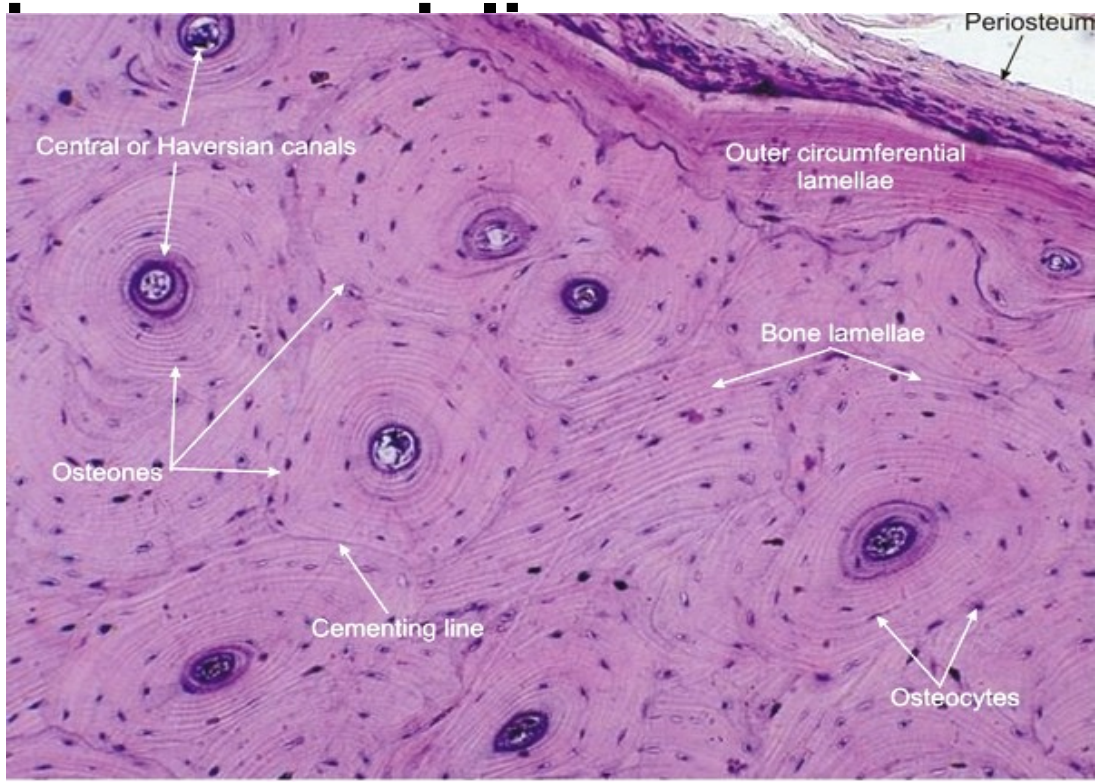
- **Both canals <u>are lined by</u> osteogenic cells, osteoblasts and osteoclasts.**
- **Contain loose C.T. with blood vessels and nerves.**



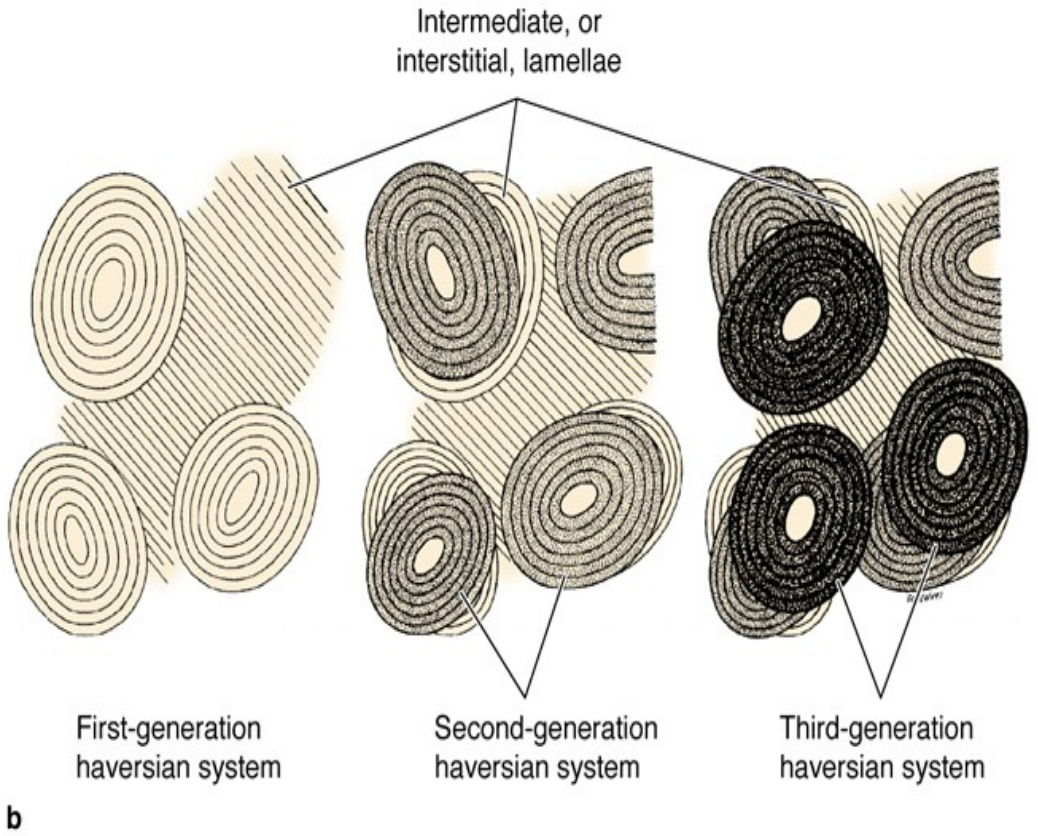
http://histonano.com/books/Junqueira's%20Basic%20Histology%20PDF%20WHOLE%20BOOK/New%20folder%208/loadBinary_009.gif

2- Interstitial lamellae

Irregular calcified bone lamellae . They represent remnant of old Haversian system d



http://tse2.mm.bing.net/th?id=OIP.M_lw0QRpczqpn6K9gh9twAHaFl&w=230&h=170&rs=1&pcl=dddddd&o=5&pid=1.1



https://www.google.com.eg/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjv8oHblpHiAhXSyYUKHd9GB3AQjRx6BAgBEAU&url=https%3A%2F%2Fairfreshener.club%2Fquotes%2Fplate-growth-epiphyseal-ossification-endochondral.html&psig=AOvVaw2hbk9D8tUfA3l08XFgv9rJ&ust=1557585043903793

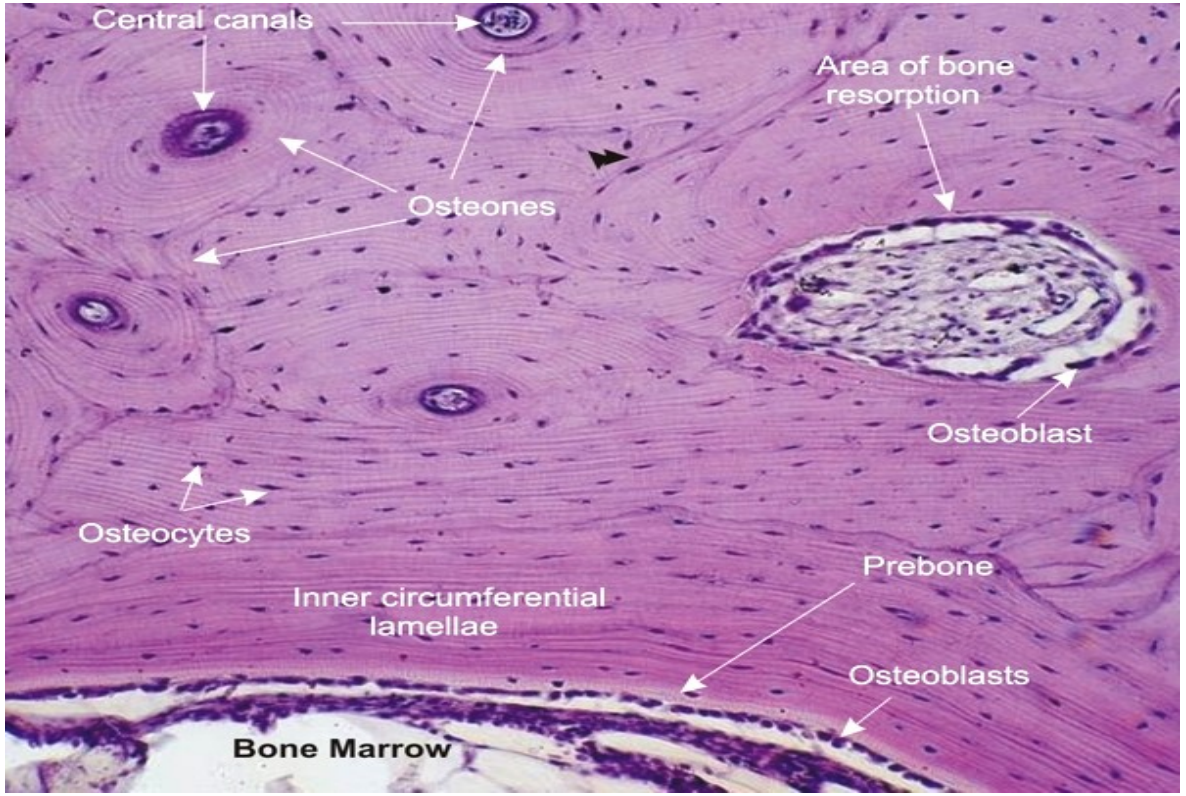
C) Inner zone

- **Inner circumferential lamellae:**

Lamellae of calcified bone matrix surrounding and parallel to the inner surface of bone

- **Endosteum**

Lining the bone marrow cavity.



https://tse3.mm.bing.net/th?id=OIP.YwGmJfk6O5uQD5ZOZfx_QwHaGp&pid=Api&P=0&w=300&h=300

Lecture Quiz

-The outer circumferential lamellae are present:

A. Around endosteum
B. Under periosteum
C. Between Haversian systems
D. Around the Haversian canal

2- Cancellous Bone

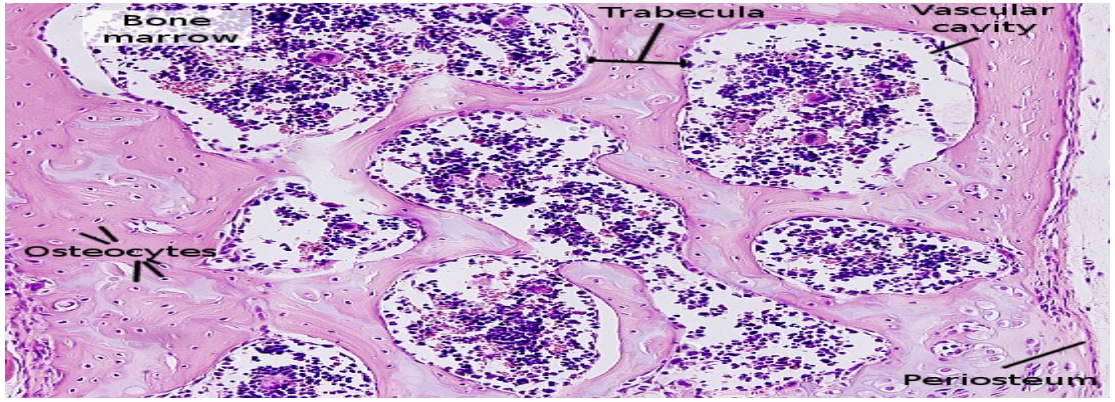
Microscopic structure:

- **It is spongy in shape.**

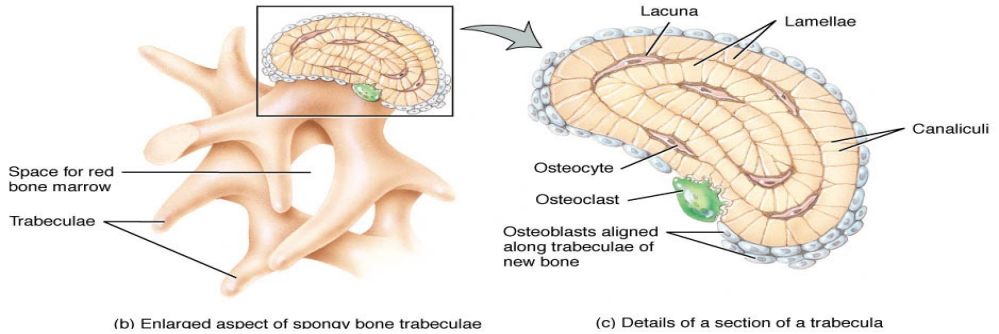
- **Composed of branching and anastomosing trabeculae of bone with ;** numerous interconnecting marrow spaces of various sizes are present among the bone tissue.

- The matrix of the bone is lamellated.

- **Bone trabeculae are formed of Irregularly arranged bone lamellae, osteocytes inside**



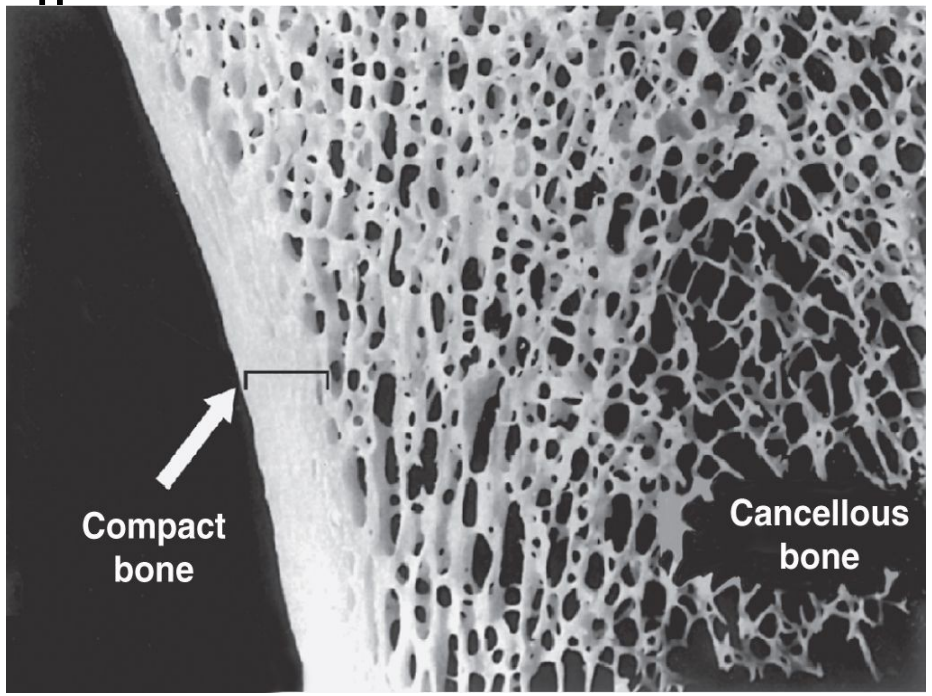
https://mmegias.webs.uvigo.es/02-english/a-iconos/hueso-trabecular.png



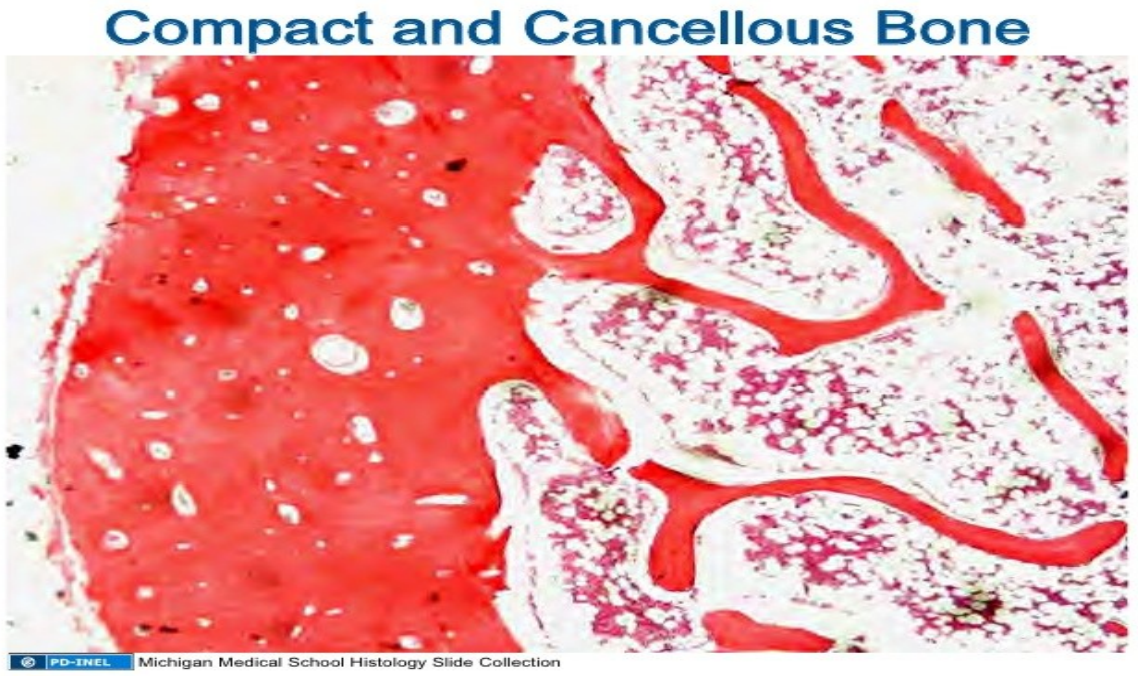
https://www.google.com.eg/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwi4-9qnmJHiAhWE4IUKHePMDuQQjRx6BAgBEAU&url=https%3A%2F%2Fcellcode.us%2Fquotes%2Fdistal-epiphysis-function.html&psig=AOvVaw0u-59T4ixixb9NgCI_Iq8h&ust=1557585499904526

- Bone marrow spaces are lined by endosteum containing: **osteogenic cells, osteoblasts and osteoclasts**.

- Spongy bone is always covered by a layer of compact bone to protect it.



https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQs6mZZ9wQK3c7iuOrilVdmldYFZnibV7EACv54f72FS6CwrHQZ5w



https://image.slidesharecdn.com/100808-histo-cartilageboneho-111024175218-phpapp01/95/100808-histology-cartilagemature-bone-47-728.jpg?cb=1319479087

Osteogenesis/ Development of bone/ Ossification

It is the process of bone formation

In the intrauterine life, formation of bone occurs by two ways:

Intramembranous ossification

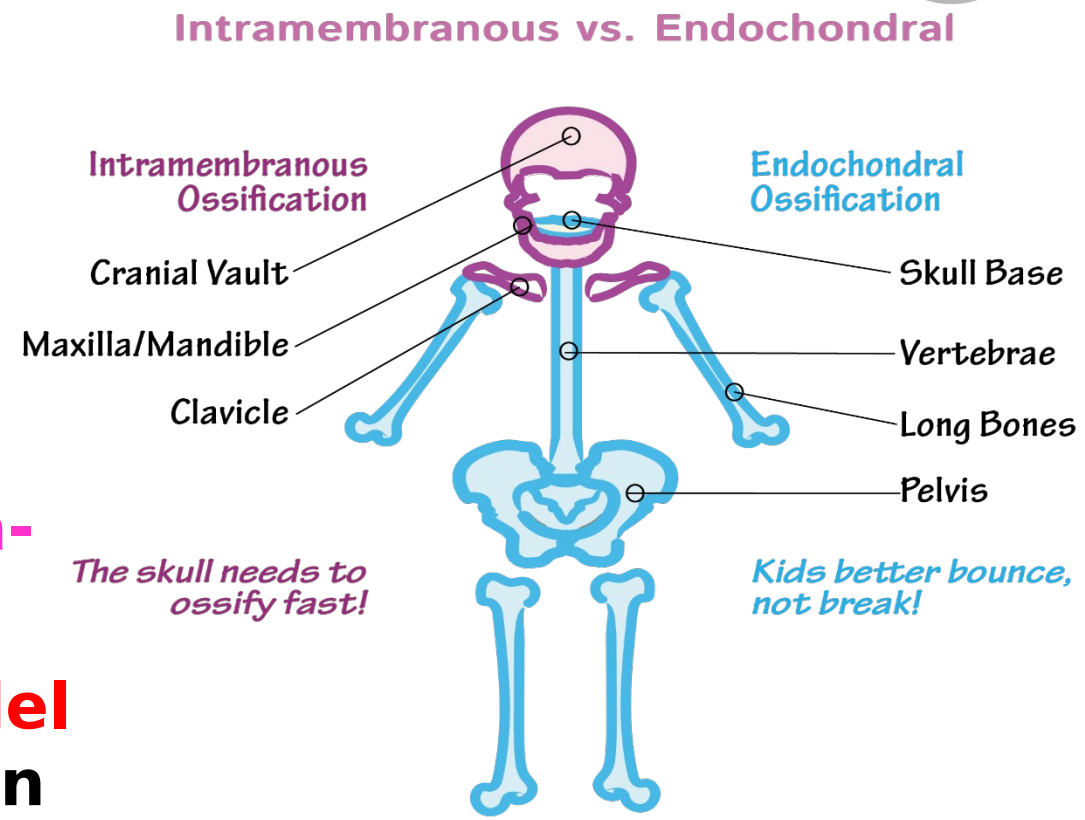
- **Flat bones as bones of skull vault, maxilla, mandible & Clavicle**

Endochondral or intra-cartilagenous ossification

- Long & short bones
- **Vertebrae**

1- Intramembranous ossification :

- **Bone is formed from a mesenchymal membrane.**



http://d1j63owfs0b5j3.cloudfront.net/term/images/538-1488452477865.png

2- Endochondral Ossification (Intra-cartilagenous)

Bone is formed as a cartilage model (for the future bone) which is then destroyed and replaced by the bone.

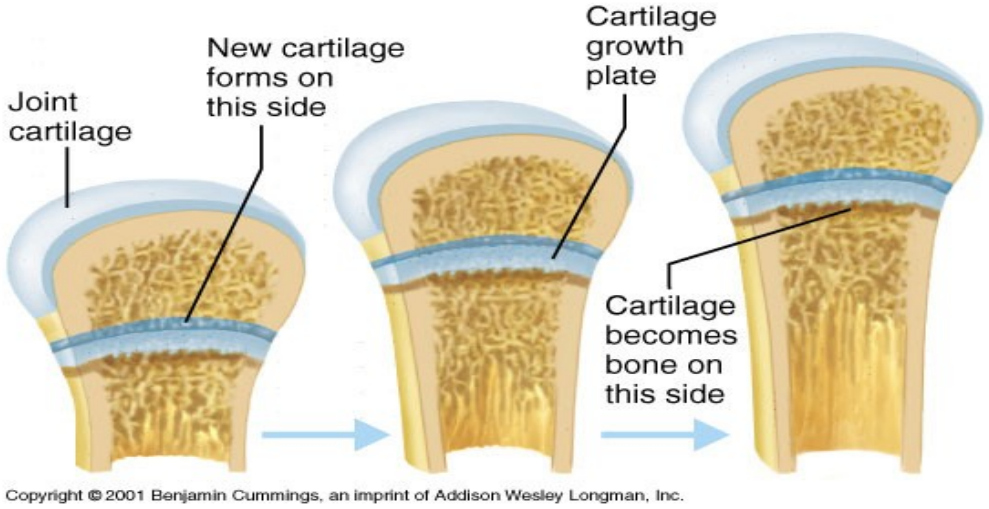
Bone Growth

A- Growth in width (Appositional growth):

Bone growth involves both continuous resorption of bone tissue formed earlier by **osteoclasts** and the simultaneous laying down of new bone by **osteoblasts** at a rate **exceeding that of bone removal**. This maintains each bone's shap

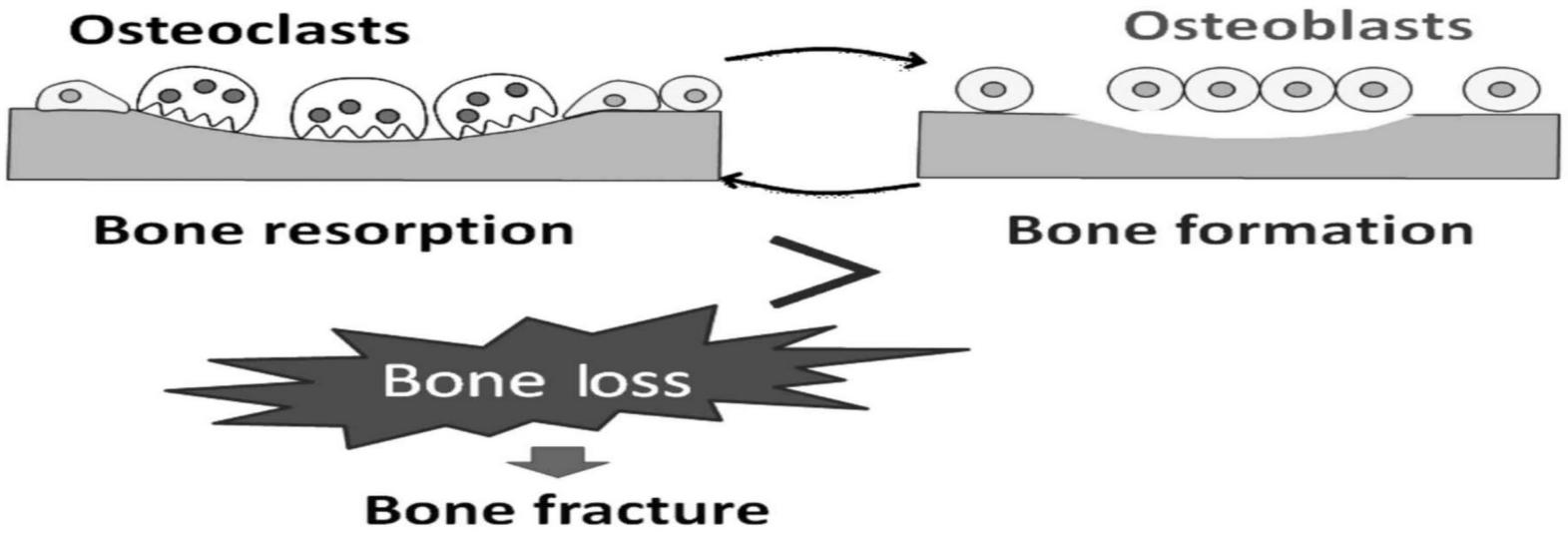
B- Growth in length (interstitial growth) :

Long bone continue to grow in length as a result of interstitial growth of the epiphyseal plate of cartilage



https://www.google.com.eg/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwi5kuXom5HiAhVOJhoKHc_AACgQjRx6BAgBEAU&url=https%3A%2F%2Fslideplayer.com%2Fslide%2F10033363%2F&psig=AOvVaw1pLYL-tXC3Rstyo4HYY41h&ust=1557586412293725

Bone remodeling is a lifelong process where mature bone tissue is removed by Osteoclast (a process called *bone resorption*) and new bone tissue is formed by Osteoblasts (a process called *ossification* or *new bone formation*).



https://www.spandidos-publications.com/article_images/ijmm/39/2/IJMM-39-02-0261-g00.jpg

Medical Applications

Effect of **Calcium & Vitamin D deficiencies** (↓ Ca in diet or ↓ Vit. D)

In children

Rickets

Defective calcification → deformed weak bone & slow growth

https://www.natural-health-news.com/wp-content/uploads/2015/02/Rickets.jpg

In adult

Osteomalacia

Decalcification of bone → weak bone & liable to fracture

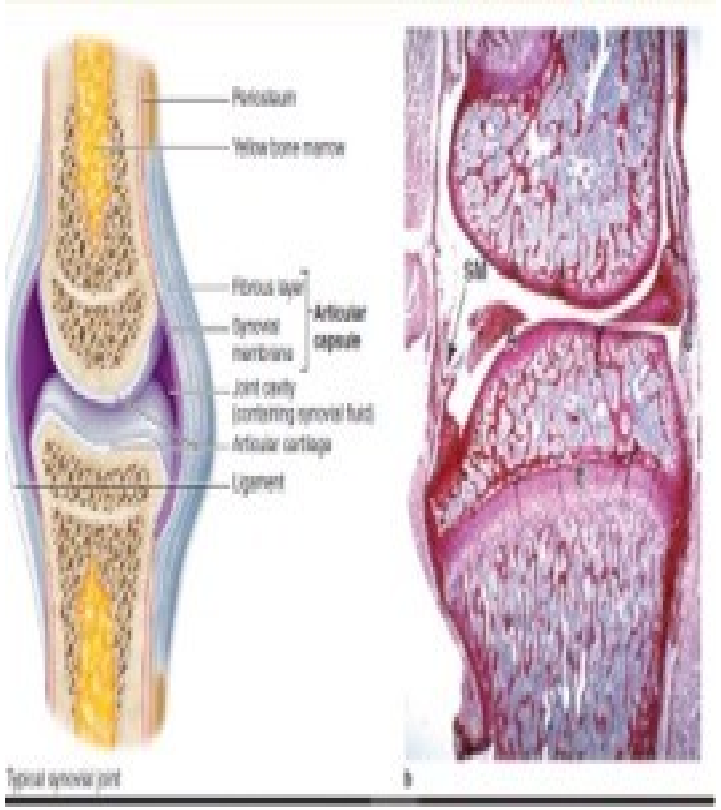
http://jewishvaluesnetwork.org/wp-content/uploads/2018/11/osteomalacia-signs-and-symptoms-best-of-rickets-disease-in-adults-bing-images-of-osteomalacia-signs-and-symptoms.jpg

Synovial Joints

- The joint cavity is lined, not by epithelium, but by a specialized connective tissue called the **synovial membrane** that extends folds into the joint cavity and produces the lubricant synovial fluid.
- **Cells lining the synovium:**

- Macrophage-like synovial cells (**type A)** remove wear-and-tear debris from the synovial fluid.

- Fibroblastic synovial cells (**type B)**, produce abundant hyaluronan and proteoglycans.



Lecture Quiz

- Cancellous bone:

A. Is formed of bone trabeculae and bone marrow spaces
B. Its bone lamellae are regularly arranged
C. Contains Haversian systems
D. Bone marrow spaces are lined by osteoclasts only

Key Points

- Microscopic structure of bone matrix.
- Microscopic structure of periosteum & endosteum.
- Differentiate between immature & mature bone.
- Histological structure of compact & cancellous bone.
- Differentiate between intramembranous & intracartilaginous ossification.
- Bone growth, remodeling & medical application.

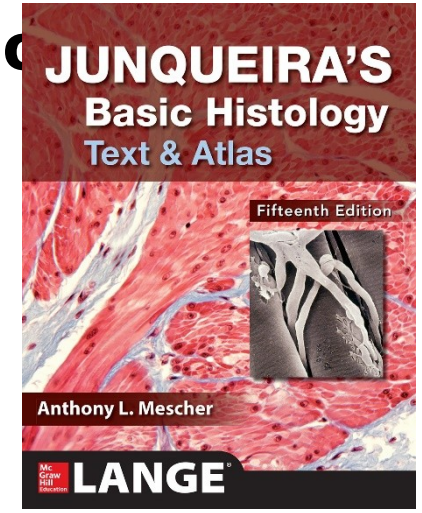
Summary

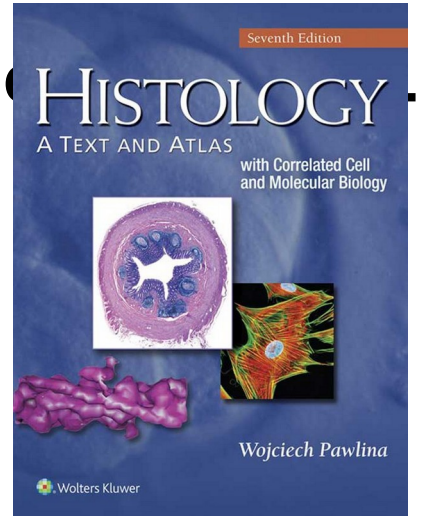
1. Periosteum is the outer membrane covering of bone
2. Endosteum is the inner membrane lining the inner surfaces of bone.
3. The calcified bone lamellae are deposited regularly in compact bone
4. The lamellae of compact bone are organized in: outer and inner circumferential lamellae, concentric lamellae and interstitial lamellae
5. The structural unit of compact bone is the Haversian system or the osteon.
6. Bone grows in width “appositional bone growth” by addition of bone matrix by the periosteum and endosteum.
7. Bone grows in length by interstitial growth of the epiphyseal plate of cartilage.

SUGGESTED TEXTBOOKS

1. **Junqueira's Basic Histology: Text and Atlas, 15th Edition by Anthony Mescher (2018)**

2. **Histology a text and atlas with correlated cell and molecular bio Pawlina 7th e .6)**





THANK YOU